429

ESTIMATING ABUNDANCE OF PINK AND CHUM SALMON FRY IN PRINCE WILLIAM SOUND, 1957

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ABSTRACT

Salmon fry enumeration studies conducted on eight streams in the Prince William Sound area of Alaska provided estimates of the numbers of pink and chum salmon fry produced in streams of that area in 1957. The studies were conducted to provide a basis for predicting returns of adult salmon.

A method of deriving estimates of fry production from trapping experiments and excavations of pre-emergent fry in intertidal gravel was presented.

Timing and duration of migration of chum and pink salmon fry were recorded, and recommendations were made for future fry sampling programs.

INTRODUCTION

This paper presents the methods used to enumerate salmon fry that migrated from streams in the Prince William Sound area of Alaska in 1957. The work was part of the Bureau of Commercial Fisheries program to determine the causes of fluctuations and general decline in the numbers of pink salmon *(Oncorhynchus gorbuscha)* and chum salmon *(O. keta)* that enter the Sound.

Fluctuations in abundance can mean serious economic losses to fishermen, and uncertainty about the size of salmon runs expected each year makes it difficult for the salmon canning industry to plan operations from year to year and complicates management of the fishery. Reliable methods for predicting the size of the runs would be of great benefit to the industry and to the regulatory agency charged with insuring adequate escapement of adult salmon through the fishery to the spawning streams.

The best available method of forecasting salmon runs in Alaska has been based on the numbers of adults spawning in the streams; however, the relationship between numbers of spawning adults and subsequent return from the sea is not always direct. Large escapements have yielded poor returns, and, conversely, low numbers of adult spawners have sometimes produced good returns. A method

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is needed for predicting the sizes of adult runs based on the abundance of young salmon at some time in their life cycle after the greater proportion of highly variable mortalities has occurred.

An estimate of the size of returning adult runs based on the numbers of young fry migrating to the sea in the spring should be more reliable. In the winter, high and often quite variable mortality occurs during egg development and fry emergence. By the time the fry are migrating seaward most of the hazards confronting young fish have already been encountered. Predictions of adult abundance based on counts of the young at this stage should have a much lower chance for error.

This thinking was the basis for the salmon fry counting program that the Bureau initiated in the Sound in 1957. The program had the broad objectives of providing information about the numbers of young salmon leaving the streams, so that variations in fresh-water survival could be detected, and of developing a means of predicting the size of adult pink and chum salmon runs.

Measuring fry abundance in the Prince William Sound area is largely a matter of sampling the 194 salmon streams that flow into the Sound.

The specific objectives of the 1957 work reported here were as follows: (1) Develop techniques for trapping salmon fry as they leave fresh water; (2) determine the numbers of fry migrating from areas upstream from traps in selected streams; (3) field test a method of sampling stream intertidal areas; (4) estimate abundance of fry in the intertidal area; and (5) estimate total abundance of pink and chum salmon fry migrating seaward from all streams entering Prince William Sound.

EXPERIMENTAL PROCEDURE

It is obviously impractical to conduct fry counting operations on all of the 194 salmon streams of Prince William Sound. The problem, therefore, was to select a sample of streams that would provide an unbiased estimate, with established confidence limits, of the total migration of fry from all streams.

The experimental design selected in the planning stages was that of stratified random sampling, with proportional allocation of the sample size to the various strata. Streams were grouped, or stratified, by size and by timing of the salmon runs, and those in which migrating fry were to be counted were drawn at random from each stratum.[1]

Traps were to be installed in each stream selected and fished throughout the period of seaward migration of fry. The number of fry leaving each sample stream was to be estimated by measuring the proportion of waterflow strained by the traps and by conducting marking and recovery experiments. The estimates were to be inflated for the various strata and combined into an estimate of the total number of fry migrating from above the traps for all of Prince William Sound.

The numbers of fry produced in intertidal areas below the traps were to be estimated separately and by a different technique. Fry were to be excavated from the gravel of sample streams with the use of a quadrat sampling device. The average number of fry per square yard of gravel was then to be multiplied by the total number of yards in which spawning occurred. Intertidal estimates were to be combined with above-trap estimates for the grand total of fry for all streams of the Sound.

It was not surprising that under the difficult field conditions encountered, this sampling plan was not fully implemented. A description of the sampling actually accomplished, details of the traps and the methods of fishing them, and the methods of deriving estimates of the numbers of fry follow.

Method of Stratifying Streams

Streams were stratified by the size of the spawning run and the timing of the runs of adult pink salmon. Streams in which the adult escapement had averaged more than 5,000 pink salmon during the 10 years from 1946 to 1956 were designated "major," and those with less

[1] Although not selected at random, a stream at Olsen Bay was included, because studies had been done there previously and facilities were available.

than 5,000, "minor." Streams in which the escapement appeared by July 27 were termed "early-run," those in which fish arrived in late July and the peak of spawning occurred between August 10 and 20 were termed "middle-run," and those in which the peak of spawning occurred after mid-August were termed "late-run." The result was six strata.

Apparently, the fishery takes most of the pink salmon from the middle-run streams. To some extent, the categories early-run, middle-run, and late-run coincide with geographical areas. For example, most of the streams in the Port Wells area are early-run, and those in the outer islands are late-run (fig. 1).

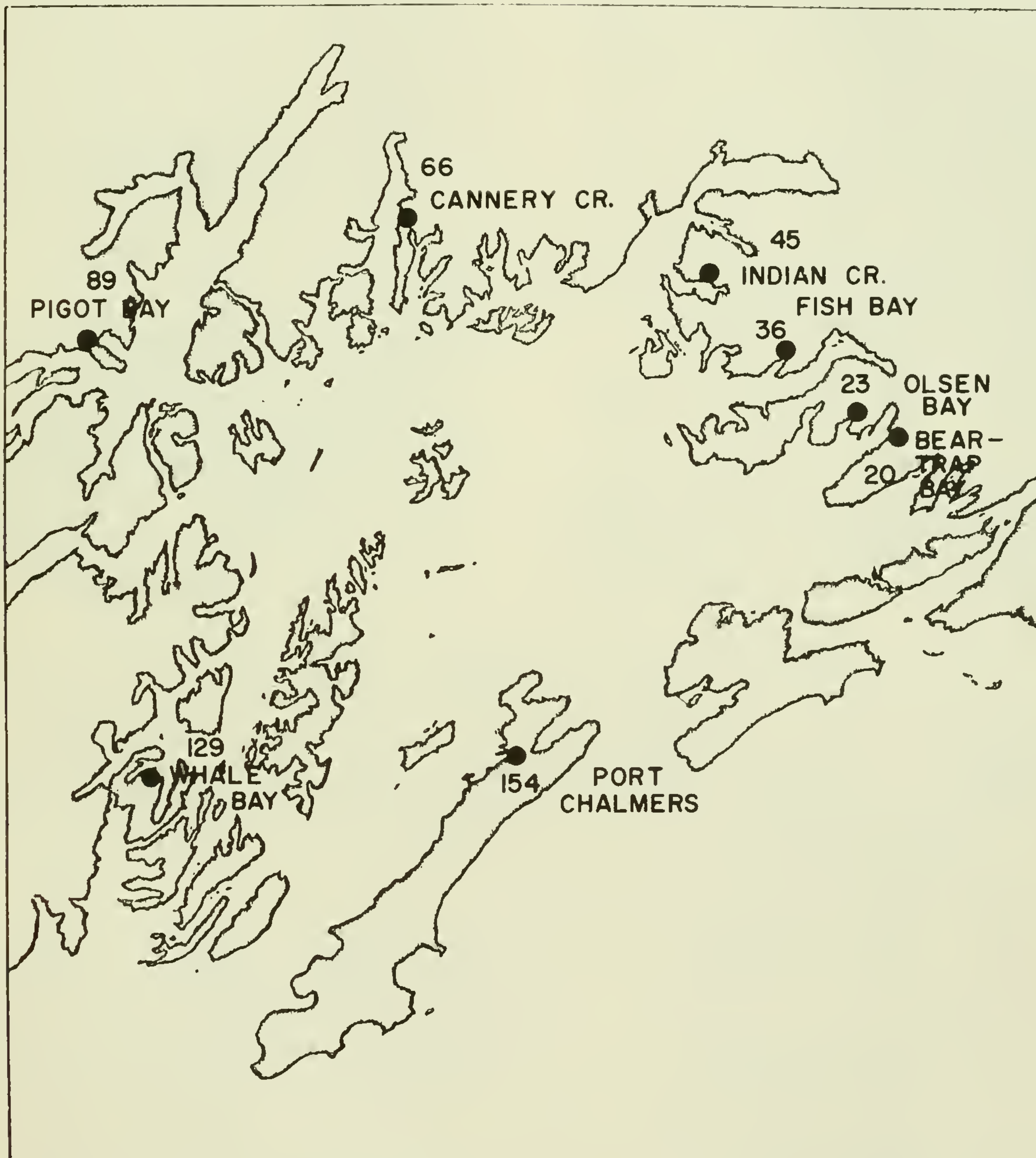

Figure 1.--Fry trapping stations in Prince William Sound, Alaska. Streams designated by numbers shown in table 1.

Streams that were sampled are listed by number, name, and stratum in table I. The estimated escapement in 1956 is given for the streams that were studied.

Limited facilities restricted sampling to eight stations, and even this number proved a strain on available resources. As a result, proportional allocation of the sample of eight among the six strata was not possible, and efforts were concentrated on strata I, III, IV, and V, which included the major salmon producing streams. Omitting strata II and VI from the sampling plan prevented estimating fry migrations from streams in these strata.

Appended to this report is a list by geographical area of the streams in Prince William Sound. For future reference, the numbers assigned to streams in 1957 and those assigned in previous years and the stratum to which each stream has been assigned are given.

Description and Method of Fishing Traps

Rectangular metal traps (fig. 2) were installed in the eight study streams at the earliest possible date after April 1 consistent with ice conditions. The traps were located above the influence of tides in a line perpendicular to the streamflow. The number installed at the various stations varied with the width of the stream. The area of the array of traps was approximately 10 percent of the total stream cross-sectional area. The open ends of the traps faced upstream, and the tops were above water so that the entire depth of water was fished.

Typical of the problems encountered in the field were those experienced at Olsen Bay. Rectangular 3-foot traps were installed at this station (fig. 3), and operations began April 2. Melting snows and high tides raised the stream to a level exceeding 12 feet above mean low water, which overtopped the traps periodically. Because of this interference, the 3-foot traps were replaced with 5-foot ones so that all water depths could be sampled. Operations were discontinued at Olsen Bay on July 5.

Fishing began on April 2 at Indian Creek where the installation was moved four times in attempts to locate a site where traps would not be flooded by high tides. When traps were moved to a site above the influence of 14-foot tides, the spawning area was completely below the traps. The final installation on Indian Creek, which was completed on May 23, was about 250 feet below the upper limits of the spawning area. Operations were discontinued on June 19.

Table 1.--Streams selected for fry migration studies in Prince William Sound, 1957

Stratum number	Type of stream	Number streams in stratum	Stream number	Stream name	Estimated number of spawners, 1956	
					Pink salmon	Chum salmon
I	Major, early-run	5	89	Pigot Bay	56,000	8,000
II	Minor, early-run	14	--	--	--	--
III	Major, middle-run	22	20	Beartrap Bay	24,500	12,200
			23	Olsen Bay	50,400	6,800
			45	Indian Creek	33,700	2,500
			66	Cannery Creek	21,300	--
IV	Minor, middle-run	93	36	Fish Bay	900	0
			129	Whale Bay	Unknown	Unknown
V	Major, late-run	10	154	Port Chalmers	4,500	0
VI	Minor, late-run	50	--	--	--	--

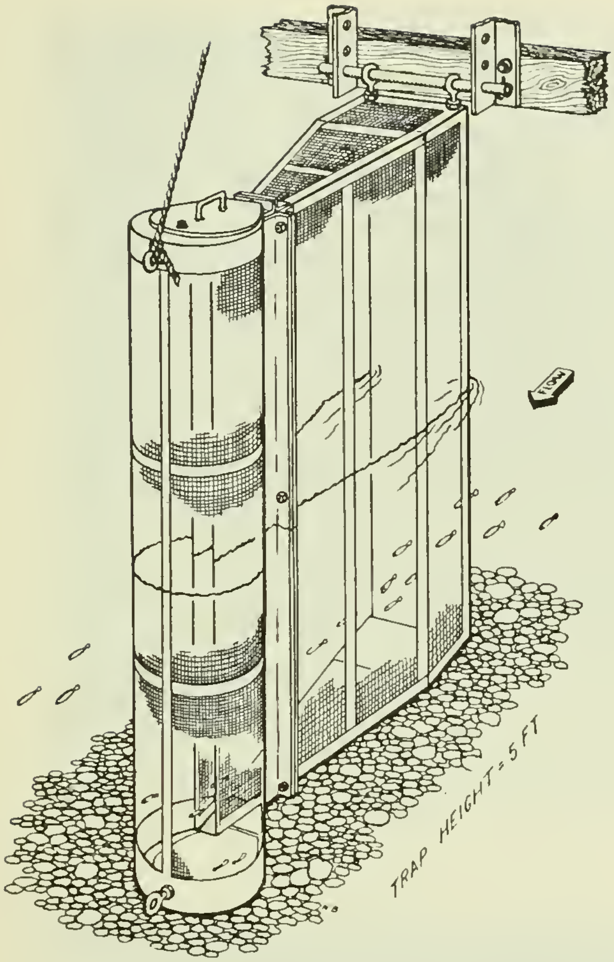

Figure 2.--Metal fry trap used in enumerating pink and chum salmon fry in Prince William Sound streams, 1957.

On April 4, fishing began at Cannery Creek (fig. 4) and Pigot Bay and continued until June 19. The first traps installed were submerged by tides, and both installations were moved upstream on May 18.

On April 9, traps were installed at Whale Bay (fig. 5). They were secured with a steel cable and were placed about 30 feet downstream from a 10-foot bank of snow and ice that completely covered the stream. The installation was removed on May 12 when it became necessary to curtail activities because of manpower limitations.

Trapping began at Port Chalmers on April 10, and on May 22 the traps were moved about 150 yards upstream from the initial site. They were fished in the new location until June 20.

At Fish Bay traps were fished in one location from April 13 through June 19.

Ice in Beartrap Bay prevented establishing a camp until April 27. Traps were installed on that date and fished until May 17.

Even though we assumed that pink and chum salmon fry migrated only between 2000 and 0800 hours, all station attendants were instructed to operate traps continuously until the migration pattern was determined, and to check traps daily at 0100, 0800, and 2000 hours. Traps were fished for 24 hours a day, except when they were being moved or cleaned, or when the attendant decided not to fish for brief periods because of high fry mortality in the traps.

Large amounts of debris washed into the traps by the increased waterflows resulting from melting snow and ice were responsible for fry mortalities. Special attention was necessary to keep the traps clean so as to insure free flow of water through them. The highest mortalities, which ranged up to about 25 percent of the fish taken, occurred at Olsen Bay where streamflows were very high and fry migrations large. Daily catches ran as high as 8,279 during the peak of the run when traps were lifted eight times a day at $2\frac{1}{2}$- to $3\frac{1}{2}$-hour intervals.

Method of Estimating Migration from Trap Catches

The method of calculating total fry migration from above the trap installation for each stream sampled was as follows:

$$T = \left(\frac{a}{b}\,100\right)\left(\frac{100}{c}\right)\left(\frac{100}{100-d}\right)$$

where a = number of fry captured by traps at a station,

b = percent of fry captured by traps,

c = percent of fry migration between original installation date and dismantling date,

d = percent of time traps were not fished while being cleaned, repaired, or moved to a better location,

T = estimated total fry migration from above traps.

Figure 3.--Fry trap installation at Olsen Bay.

Figure 4.--Fry trap installation at Cannery Creek, showing method of hanging traps and spacing of traps across stream.

Figure 5.--Fry trap installation at Whale Bay showing method of securing traps by cable, and spring snow conditions.

The percent of the fry migration that the traps captured was estimated by (1) measuring the volume of water strained by the traps and (2) determining the average percentage of marked fry captured by the traps after release in each stream.

Streamflow studies.--Prior to the field work reported here, we assumed that fry drifted downstream helplessly in the current and that the percentage of fry migration taken in traps would be directly related to the volume of water flowing through the traps. We also assumed that the volume of water strained by traps in relation to total streamflow was the same as the ratio of the total submerged trap area to the stream cross-sectional area.

To determine the validity of these assumptions, fry behavior in relation to traps was observed, and water velocities were measured with a Price Pigmy current meter at regular intervals across the stream and within the traps. The average velocity was determined by using the 0.2- and 0.8-depth method. In general, the assumptions were found to be valid.

Fry marking and recovery experiments:--Pink salmon fry were anesthetized with chlorobutanol, marked by clipping the dorsal fin, and released about 150 to 250 feet above the traps. Before their release marked fry were held in the stream in boxes made of screen (fig. 6) for several hours, and only fry that appeared to be swimming normally were released. Marked fry were released in units of 500 and were distributed across the stream. Repeated releases were made when fry were available.

Fry captured at the first trap lift after the release were examined for clipped fins. A few fish were placed in a glass jar, and the clip marks were observed as the fish swam around. Dead fish were also examined for clip marks.

Method of Estimating Abundance in Intertidal Areas

Studies of ways to enumerate fry in intertidal spawning areas (fig. 7) did not start until late in May, after most fry had emerged from the gravel. In the preliminary phases it was

Figure 6.--Marked pink salmon fry in holding boxes.

Figure 7.--An intertidal spawning area at low tide.

apparent that efforts to trap free-swimming fry in the intertidal zone would not yield quantitative data. Fry move in and out of the area with the tides, and probably an intermingling of fry from adjacent streams occurs. In 1957 therefore emphasis was on developing methods of measuring abundance of larvae while they were still in the gravel--an approach that has an advantage over continuous trapping because it is necessary to sample an area only once before fry emerge. Once sampling techniques are worked out, this method should make it possible to sample many more streams than with traps or other devices that are dependent on capturing fry as they emerge from the gravel. Of course, there is a continual mortality of fry during the time between gravel excavations and fry emergence, and caution must be taken when combining estimates derived by the two methods.

The limits of spawning areas in the intertidal zone were delineated by digging systematically along regularly spaced transects. The technique consisted of turning over the gravel with a shovel or spading fork while proceeding across and then along the stream and observing the numbers of fry and dead eggs uncovered. The absence of eggs or fry defined the seaward limits of the spawning area. The area thus defined was mapped, and the total area of intertidal spawning computed.

The average density of fry in the gravel was determined as follows: A metal sampling device suitable for use in rapid stream currents and rugged enough to withstand repeated use was developed. It consisted of a 3-foot square metal frame with two opposite sides of sheet metal and two of plastic screen (fig. 8). The sides were 2 feet high, which was about the maximum depth of water at which gravel would be excavated.

The total intertidal spawning area of a stream was divided into sections 96 feet long. Each

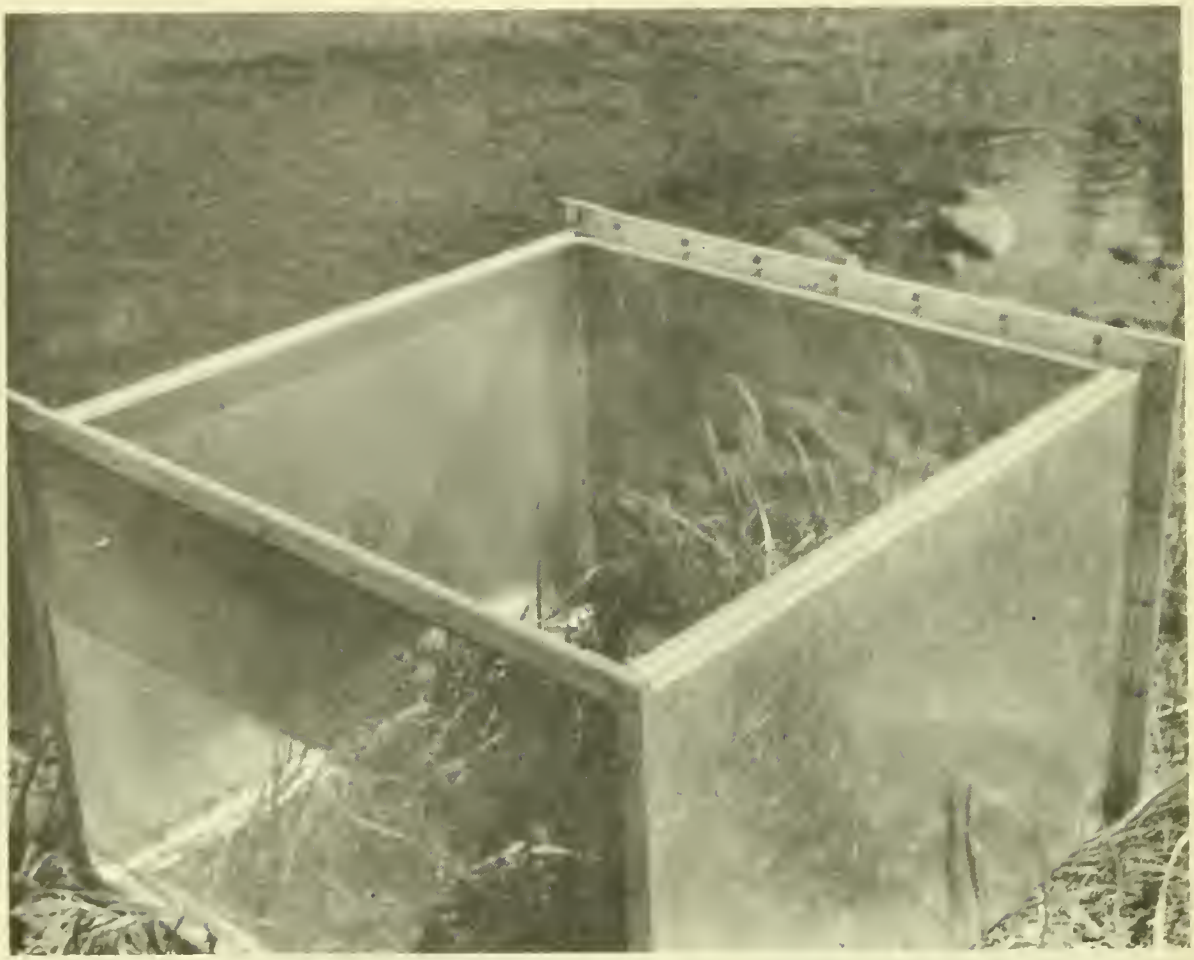

Figure 8.--Quadrat sampler used in intertidal fry studies.

section was then sampled at random; the exact location of the 3-foot square quadrat to be excavated was determined from a table of random numbers. The numbers chosen represented the distance in feet upstream and across in which a specific corner of the sampler was placed. Gravel was excavated to the maximum depth that fry occurred, and the numbers of fry, egg cases, and dead eggs were recorded.

The total number of fry in the gravel of the intertidal area of each study stream was estimated by multiplying the total area in which eggs or larvae were present by the average fry density per unit area.

MIGRATION OF FRY FROM AREA ABOVE TRAPS

Duration of Migrations

Fry migration patterns for six of the study streams are shown in figure 9. In the figure, Pigot Bay represents an early-run stream, Port Chalmers, a late-run stream, and the remainder, middle-run streams.

At Indian Creek traps were installed first at the mouth of the stream. On May 21 when high tides caused the water to flow over the tops of the traps at this location, they were moved upstream to a location known to be above

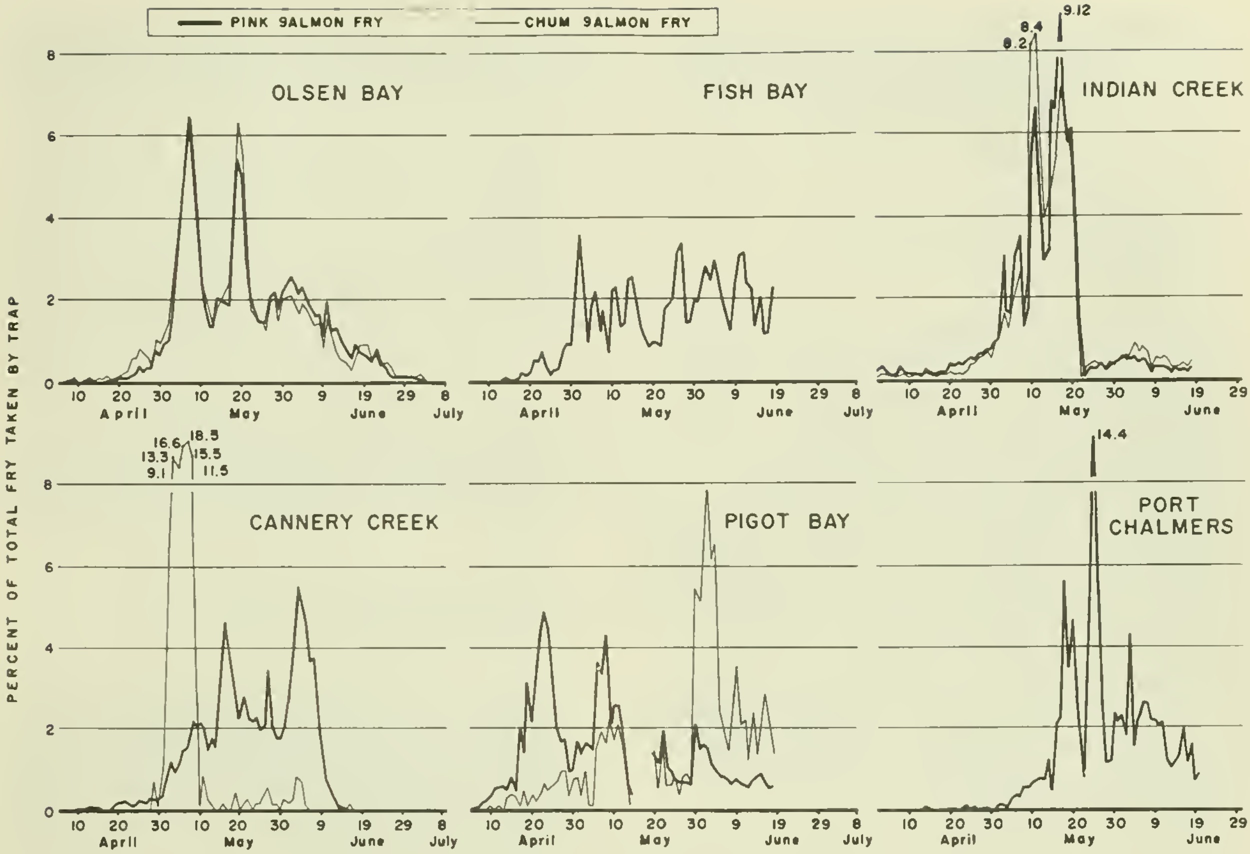

Figure 9.--Pink and chum salmon fry migration patterns for six study streams in Prince William Sound area.

the influence of 14-foot tides. One day's fishing resulted in a zero catch, and the traps were moved to a location about 250 feet further downstream. Large catches were never made after May 21 when the traps were moved, although this may have reflected a normal decline in the migration. Catches probably would have been larger after May 20 if traps had fished in the original position, since there is a considerable amount of spawning area between the sites. Assuming this to be true, the percentage of total catch as plotted in figure 9 would have been lower before May 21 and higher after May 20, if the traps had not been moved.

The migration patterns for pink and chum salmon fry were similar in each stream that produced both species, with the exception of Pigot Bay and Cannery Creek. Traps were not fished at Pigot Bay between May 12 and May 20 as a result of a severe storm on May 12 which washed out the installation. At Pigot Bay the pink fry migration reached a peak during April, and the chum migration peaked much later. At Cannery Creek the reverse was observed, with the chum fry migration reaching a peak during early May and the pink fry migration peak occurring later.

If results from the study streams are representative of the various strata, fry migrations in 1957 began in early-run streams about April 10, in middle-run streams after April 20, and in late-runs streams after May 1.

Fishing at Olsen Bay was continued through July 4 to determine if the complete migration had occurred by June 19, when the other stations were closed. Between June 19 and July 4, 3,263 pink and 1,828 chum salmon fry were taken. This represents 3.6 percent of the pink and 4.5 percent of the chum salmon frv taken and suggests that a small percent of the runs in other streams may have occurred after the traps were removed.

Terminations of the migrations were not observed in any of the streams except Cannery Creek and Olsen Bay, where they ended on June 17 and July 4, respectively. After these dates, only insignificant numbers of fry were taken.

Proportion of Fry Captured by Traps

Comparison of results of marking experiments with volume studies suggests that where water velocities were high, there was better agreement between the two methods of determining the proportion of fry captured by traps than when velocities were low (table 2). The differences between percent of water volume strained and percent of fry recaptured were large in some instances, and a choice of method and the resultant data had to be made. One explanation of the discrepancies between the two methods derives from inadequate sampling. At some of the study streams only one marking and recovery experiment was conducted, which was probably insufficient to establish the recapture rate accurately.

Behavior of the fry in relation to the traps offers an explanation of why the percent of total streamflow strained by the traps was higher than the percent of marked fry recovered. Both pink and chum salmon fry avoided trap installations when stream velocities were less than 2 feet per second. Frequently fish were observed suddenly increasing their swimming speed when they neared the traps. On a few occasions they would swim downstream and then suddenly turn 90 degrees when they neared the traps. These reactions may have been caused by the complete trap installation instead of an individual trap, but no fish showing this avoidance reaction was observed to enter a trap. It is assumed that marked fry behaved the same as unmarked fry; therefore, we decided that the marking and recovery results more nearly represent the trapping ratios. This method was used in computing estimates of the number of fry that migrated from above the traps. No marking experiments were conducted at Whale Bay and Beartrap Bay. The percentages of fry captured by traps at these two stations were estimated from streamflow studies.

Adjustments for Incompletely Trapped Streams

Trapping was discontinued at Whale Bay on May 12. To get a rough estimate of the total migration, we assumed that the fry run there followed a course similar to fry runs in other middle-run streams (Olsen Bay, Fish Bay, Indian Creek, and Cannery Creek). The average percentages of the total catch at these four streams for the first part of the fry migration, which extended through May 12, were 26.3 for pink salmon and 33.2 for chum. It seems reasonable to assume that the seaward migration of fry from Whale Bay is timed approximately the same; therefore, by extrapolation we believe that if traps had fished throughout the

Table 2.--Comparison of streamflow studies and marking--recovery experiments for eight streams in Prince William Sound during the 1957 fry migration

	Average velocity	Volume	Volume strained	Marked fry recaptured	Volume studies	Marking-recovery studies	Fry marked
	(f.p.s.)	(c.f.s.)	Percent	Percent	Number	Number	Number
Pigot Bay	2.2	109	6.4	4.8	4	4	1,900
Beartrap Bay	2.9	101	12.2	--	1	0	0
Olsen Bay	1.9	95	13.5	13.3	4	3	1,900
Indian Creek	1.4	72	7.7	4.4	1	1	500
Cannery Creek	0.9	38	8.4	3.8	4	4	2,000
Fish Bay	1.1	7	11.7	10.4	5	1	210
Whale Bay	1.3	26	10.7	--	1	0	0
Port Chalmers	0.8	9	10.0	2.2	2	1	500

migration, the catch at Whale Bay would have been approximately 45,626 pink salmon and 945 chum salmon.

Data collected at Beartrap Bay were treated in the same manner. Fishing was continued through May 16, when it was necessary to close the station. By that time, 34.6 percent of the pink and 40.1 percent of the chum salmon fry had migrated at Olsen Bay, Fish Bay, Indian Creek, and Cannery Creek.

It is doubtful, however, that 34.6 percent and 40.1 percent had migrated at Beartrap Bay when fishing ceased. This stream is considered atypical of other middle-run streams, at least when considering the time of fry migration in 1957. Fry migrations began about April 10 at all middle-run streams studied except Beartrap Bay. Ice prevented the installation of traps at that location until April 27, at which time catches had greatly increased at all other middle-run streams being sampled. At Beartrap Bay, however, catches were small during the first days of fishing, indicating that the beginning of the migration was being sampled. Also, daily catches remained relatively small (310 pink and 142 chum salmon fry) through May 16 when sampling had to be discontinued. The peak migration at Beartrap Bay, therefore, probably occurred at a later date than at other middle-run streams.

Number of Fry Migrating from above Traps

Estimates of the number of fry migrating from above the traps in the eight study streams (table 3) were calculated from the formula

$$T = \left(\frac{a}{b} 100\right) \left(\frac{100}{c}\right) \left(\frac{100}{100-d}\right)$$

The values of 100 percent in the column "Percent of migration period fished"[2] are somewhat arbitrary since a small but unknown number of fry came downstream after our studies were terminated.

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[2]Refer to formula page 5 for explanation of column headings.

ABUNDANCE OF PRE-EMERGENT FRY IN INTERTIDAL AREA BELOW TRAPS

Table 4 summarizes the results of excavations in intertidal areas where spawning was known to occur. In deriving the estimates, we assumed that the fry produced in the intertidal area before the quadrat sampling emerged in the same pattern as the upstream fry and that the bulk of the fry estimated in the intertidal area survived to migrate out of the gravel. Data are not included for study streams at Olsen Bay, Whale Bay, and Beartrap Bay, since no intertidal excavations were accomplished at these stations. Rough estimates of the abundance of fry in the intertidal zone at these three locations were made on the basis of the fraction of parent spawners observed to use the area below the traps.

The estimates of fry presented in table 4 are minimal because:

1. The studies were conducted late in the migration, and the percent of the fry that had already emerged in the intertidal area could not be determined exactly. Also, some of the fry may migrate from upstream and seek refuge temporarily in the intertidal gravel.

2. Stream velocities of about 2 feet per second caused difficulties in placing the sampling device and in keeping it stationary. High velocities also caused gravel to be washed into the area being sampled.

3. Stream velocities of over 3 feet per second made it impossible to sample some areas. Velocities ranging above 3 feet per second were recorded at times in Beartrap Bay, Olsen Bay, Indian Creek, Pigot Bay, and Whale Bay.

4. Streambottom irregularities made it difficult to place the trap in some locations, and removing boulders and gravel so that the trap would be slightly submerged in the gravel may have caused some fry to be washed from the sample area without being detected.

5. Digging in depths of 1 foot or greater sometimes resulted in gravel sliding into the

Table 3.--Estimated pink and chum salmon fry migration from above traps in eight streams, Prince William Sound, 1957

Sample stream and species captured	Number captured by traps	Percent captured by traps	Percent migration period fished	Percent trap fishing time lost[1]	Estimated number above traps
Pigot Bay					
Pink	38,347	[2] 4.8	100	6.8	857,000
Chum	1,056				24,000
Beartrap Bay					
Pink	2,447	[3] 9.5	[4] 34.6	7.9	81,000
Chum	1,247		[4] 40.1		36,000
Olsen Bay					
Pink	90,398	[2] 13.3	100	4.7	713,000
Chum	40,816				322,000
Indian Creek					
Pink	19,553	[2] 4.4	100	1.0	449,000
Chum	10,353				238,000
Cannery Creek					
Pink	40,757	[2] 3.5	100	.7	1,173,000
Chum	708				20,000
Fish Bay					
Pink	3,125	[2] 11.7	100		27,000
Chum	0				0
Whale Bay					
Pink	9,901	[3] 10.7	[4] 26.3		352,000
Chum	238		[4] 32.2		7,000
Port Chalmers					
Pink	6,588	[2] 2.2	100	.2	300,000
Chum	0				0

[1] Estimated from migration pattern of four other middle-run streams.
[2] From fry marking and recovery experiments.
[3] From streamflow studies.
[4] Time lost moving, cleaning, and repairing traps.

hole from under the edges of the trap, forming openings through which fry and eggs could escape or enter.

6. Fry that were located through excavating may have moved from redds elsewhere.

7. Excavating gravel with shovels and digging forks was not considered efficient because the work was difficult and time consuming, and even when personnel worked only for relatively short periods, they became tired and failed to detect all fry and eggs.

TOTAL NUMBER OF FRY PRODUCED IN EIGHT STUDY STREAMS

The total number of fry produced at Cannery Creek, Pigot Bay, Indian Creek, and Fish Bay can be estimated by adding the upstream (trapped) fry estimates to the intertidal fry estimates (from tables 3 and 4).

Assumptions must be made regarding Whale Bay and Beartrap Bay data. Fry trapping was discontinued at these stations in midseason.

Table 4.--Estimates of pink and chum salmon fry produced in intertidal spawning areas, Prince William Sound, 1957

Stream, sampling date, and species caught	Intertidal spawning area (sq. ft.)	Number quadrats sampled	Area sampled (sq. ft.)	Total percent area sampled	Average number recovered per sq. ft.			Estimated fry in gravel at time of digging	Estimated percent fry emerging prior to digging[1]	Estimated total fry produced in intertidal area
					Egg fragments	Dead eggs	Fry			
Pigot Bay										
June 1, 2, 3										
Pink	146,100	49	441	0.30	0.51	0.84	3.94	575,563	86.1	4,100,000
Chum							.04	5,844	48.6	11,000
Indian Creek										
June 13, 14										
Pink	86,618	52	468	0.54	0.78	1.52	.84	72,759	98.6	5,200,000
Chum							.27	23,387	98.1	1,200,000
Cannery Creek										
May 26, 27, 28										
Pink	111,779	56	504	0.45	1.57	1.00	0.67	74,891	54.1	160,000
Fish Bay										
June 14, 15										
Pink	6,039	19	171	2.83	0.00	0.00	0.15	906	92.2	11,000
Port Chalmers										
June 5, 6										
Pink	21,500	26	234	1.09	0.74	1.48	0.56	12,040	75.8	50,000

[1] Estimated from proportion of upstream fry captured in traps through first day of excavation studies.

For purposes of estimating the total migration at these stations the last part of the fry run, i.e., the portion not sampled, was considered to be similar to the last part of the run at other streams where complete trapping data were obtained. Furthermore, at these two stations and at Olsen Bay the numbers of fry produced in the intertidal areas were estimated from observations of the percentage of the total run of adults that had spawned in the intertidal area. These assumptions are dubious, and estimates of the total number of fry presented in table 5 should be used with caution.

FRY MIGRATION FROM MAJORITY OF STREAMS IN PRINCE WILLIAM SOUND

Sample averages were inflated to total fry estimates by multiplying the average migration per stream by the number of streams in the respective strata. The results are summarized in table 6. No attempt is made to assign confidence limits to the estimates because of the inherent weaknesses in the sampling program.

Table 5.--Estimation of total fry production for eight streams, Prince William Sound, 1957

Stream and species	Fry migrating from above traps	Fry migrating from intertidal area	Total
Pigot Bay			
Pink	857,000	4,100,000	4,957,000
Chum	24,000	11,000	35,000
Beartrap Bay			
Pink	[1] 81,000	[2] 9,000	90,000
Chum	[1] 36,000	[2] 4,000	40,000
Olsen Bay			
Pink	713,000	[2] 1,435,000	2,148,000
Chum	322,000	[2] 648,000	970,000
Indian Creek			
Pink	449,000	5,200,000	5,649,000
Chum	238,000	1,200,000	1,438,000
Cannery Creek			
Pink	1,173,000	163,000	1,336,000
Chum	20,000	0	20,000
Fish Bay			
Pink	27,000	11,000	38,000
Whale Bay			
Pink	[1] 352,000	[2] 18.000	370,000
Chum	[1] 7,000	[2] 300	7,300
Port Chalmers			
Pink	300,000	50,000	350,000

[1] Estimated from migration patterns of four other middle-run streams (see also table 3).
[2] The percent of fry emerging from intertidal area roughly estimated from percent of total run of adults spawning in intertidal area. At Whale Bay this was 5 percent, at Olsen Bay 67 percent, and at Beartrap Bay 10 percent.

Table 6.--Estimated pink and chum salmon fry migrations from certain strata, Prince William Sound, 1957

Stratum number	Type of stream	Number streams in stratum	Species	Average migration per stream	Migration per stratum
I	Early-major	6	Pink Chum	4,958,000 35,000	30,000,000 200,000
II	Early-minor	13		Not sampled	Not sampled
III	Middle-major	22	Pink Chum	2,300,000 625,000	51,000,000 14,000,000
IV	Middle-minor	93	Pink Chum	204,000 3,500	19,000,000 300,000
V	Late-major	10	Pink Chum	350,000 0	3,500,000 0
VI	Late-minor	50		Not sampled	Not sampled

DISCUSSION AND CONCLUSIONS

The pink and chum salmon fry enumeration program in Prince William Sound in 1957 showed clearly that the amount of sampling required to obtain precise estimates of the total seaward migration of fry would be very expensive. It became apparent that traps were not entirely satisfactory for estimating fry abundance. The prolonged migration and the need for attending the traps day and night required that each study stream be manned continuously over a 3-month period. Furthermore, vulnerability to high tides and unusual streamflows required that traps be fished upstream from most intertidal areas where a large proportion of pink salmon spawn. Predators such as Dolly Varden trout and sculpins introduced unknown errors by entering the traps and devouring large numbers of fry. Also, the 1957 studies revealed the need for studying the behavior of fry in relation to the traps.

Estimates of pre-emergent fry abundance in intertidal areas are considered by the authors to be gross and to have limited usefulness because of the exploratory nature of the 1957 work. The excavation of sample quadrats with shovels and forks proved to be inefficient. For a more efficient sampling program, fry digging should be accomplished before fry begin to emerge so as to include all of the fry population in the sampling program. Extent of adult intertidal spawning can be determined for each study stream in the fall, thereby limiting the area to be sampled. Variability in fry abundance and the distribution of fry in stream gravels should be considered in determining the number and location of samples required for estimating fry abundance. The 1957 data provide a basis for future fry sampling studies.

It was not possible to estimate the total fry migration from Prince William Sound streams in 1957 with confidence limits because of limitations in the sampling program. Much was learned, however, about the duration and character of the fry migration in several types of streams and the extent of intertidal spawning was more fully appreciated.

SUMMARY

1. Pink and chum salmon fry trapping was initiated in Prince William Sound streams in 1957 to provide a basis for predicting the size of subsequent adult runs and to provide a measure of the survival of young salmon in fresh water.

The objectives of the 1957 work were (1) develop sampling methods for estimating the abundance of fry in the stream proper and in

intertidal areas and (2) estimate the total number of fry produced in streams entering the Sound.

2. The experimental design for estimating production of fry was one of stratified random sampling with proportional allocation of the sample. Streams were stratified by size and timing of adult spawning migrations. Eight streams were included in the sample. Different techniques were used to estimate the production of fry in the stream proper and in the intertidal areas.

3. Pink and chum salmon fry migrating downstream from areas above tidal influence were sampled by means of metal traps. Traps were fished 24 hours each day throughout the migration (April, May, and June), except when they were removed for cleaning or were being relocated.

4. The proportion of seaward-migrating fry captured by the traps in each stream was estimated by measuring the proportion of waterflow strained by the traps and by means of marking and recovery experiments.

5. The contribution of intertidal areas was estimated by a system of quadrat sampling of pre-emergent fry in the gravel.

6. The results of intertidal sampling were combined with upstream trapping data to provide an estimate of the total fry production for the study streams. The averages for the various study streams were inflated to give estimates for each group or stratum of streams.

7. Totals of 211,116 pink salmon fry and 54,418 chum salmon fry were taken in traps from eight streams during this study. The estimated total numbers of pink and chum salmon fry produced in four strata, which include the majority of streams in the Sound, were 103,000,000 and 14,500,000 respectively.

8. In addition to providing estimates of the production of fry from the majority of Prince William Sound streams, the 1957 studies provided information needed for improving the efficiency of sampling. The timing and duration of the migrations of chum and pink salmon fry were determined. The migration patterns for the two species were usually similar in each stream, but pink salmon fry emerged much earlier at one study stream, and chum salmon fry emerged first in another stream. The excavations of many quadrat samples revealed that intertidal spawning was much more extensive than was realized prior to beginning the studies.

9. The authors concluded that more efficient means of sampling were required than was afforded by traps. The operation of fixed traps was expensive and inadequate, since a large proportion of the fry are produced in the intertidal areas below the traps. Recommendations for the design of future salmon fry sampling programs include: (1) Determine the extent of adult spawning activity in each study stream, (2) develop more practical means of extracting eggs and larvae from the gravel, and (3) consider the variability of fry distribution in establishing the amount of sampling needed.

APPENDIX

Index numbers of streams (Prince William Sound)

Location	1957 number	Old number	Stratum	Location	1957 number	Old number	Stratum
Hartney Bay	1	1	IV	Galena Bay	44	30	III
	2	2	IV		45	31	III
	3	3	IV		46	32	IV
	4	4	IV		47	33	III
	5	5	IV		48	34	IV
	6	6	IV		49	35	IV
	7	7	IV		50	35	IV
	8	8	IV		51	36	IV
	9	9	IV		52	38	IV
	10	10	IV				
	11	11	III	Sawmill Bay	53	39	IV
	12	12	III		54	40	III
	13	13	IV		55	41	IV
					56	42	IV
Gravina Point	14	1	IV		57	43	IV
	15	2	IV		58	44	III
	16	3	IV		59	45	III
	17	4	IV		60	46	IV
	18	5	IV		61	2	IV
	19	6	IV		62	3	IV
					63	4	III
Port Gravina	20	7	III		64	5	IV
	21	8	IV		65	6	III
	22	9	IV				
	23	10	III	Unakwik	66	7	III
	24	11	III		67	8	IV
	25	12	IV		68	9	IV
	26	13	III		69	10	III
	27	14	IV		70	11	III
	28	15	IV		71	11a	IV
	29	16	III				
	30	17	IV	Eaglek	72	12	IV
	31	17a	IV		73	13	IV
	32	18	IV		74	14	IV
	33	19	IV		75	15	IV
					76	16	IV
Fish Bay	34	20	III				
	35	21	IV	Ester Pass	77	17	IV
	36	22	IV		78	18	IV
	37	23	IV		79	18a	IV
	38	24	IV		80	18b	IV
	39	25	IV		81	18c	II

Location	1957 number	Old number	Stratum
Fish Bay	40	26	IV
	41	27	IV
	42	28	IV
	43	29	III
Port Wells	83	20	II
	84	21	I
	85	22	II
	86	23	I
	87	24	I
	88	24a	II
Pigot Bay	89	25	I
	89a	25	I
	90	25a	II
	91	25b	II
Blackstone Bay	92	23a	I
	93	23	II
	94	22	II
	95	21	II
	96	20	II
	97	19	II
	98	18	II
Culross Pass	99	17a	IV
	100	17	III
	101	16	IV
Port Nellie Juan	102	15	III
	103	15a	IV
	104	14	IV
	105	13	IV
	106	12	IV
	107	12a	IV
	108	11	IV
	109	10a	IV
	110	10	IV
	111	9	IV

Location	1957 number	Old number	Stratum
Ester Pass	82	19	II
Chenega[1]	121	26	IV
	122	28	IV
	123	29	IV
	124	30	IV
	125	30a	IV
Whale Bay[1]	126	35	IV
	127	36	IV
	128	37	IV
	129	38	IV
	130	39	IV
	131	40	IV
	132	43	IV
	133	44	IV
Bainbridge[1]	134	44a	VI
	135	44b	VI
	136	42	VI
	137	41	VI
Evans Island[1]	138	19	VI
	139	18	VI
	140	17	VI
	141	16	V
Latouche[1]	142	15	VI
	143	14	V
	144	13	VI
Montague[1]	145	12	V
	146	11	V
	147	10b	VI
	148	10a	VI

Index numbers of streams (Prince William Sound)--*Continued*

Location	1957 number	Old number	Stratum	Location	1957 number	Old number	Stratum
				Montague [1]	149	10	VI
Eshamy	112	8	IV		150	9	VI
	113	7	IV		151	8	VI
	114	6	IV		152	7	VI
	115	5	IV		153	6	VI
					154	5	V
Ewan Bay	116	4	IV		155	5a	VI
					156	4	V
Jackpot Bay	117	31	IV		157	1	VI
	118	32	IV		158	2	VI
	119	33	IV		159	3	VI
	120	34	IV				
				Hawkins Island [1]	189	16	VI
Knight Island [1]	160	28	VI		190	16b	VI
	161	20	VI		191	16a	V
	162	21	VI		192	15	VI
	163	22	VI		193	14	VI
	164	23	VI				
	165	1	VI				
	166	2	VI				
	167	24	VI				
	168	25	VI				
	169	26	VI				
	170	27	VI				
Hinchinbrook [1]	171	30	VI				
	172	31	VI				
	173	32	VI				
	174	33	VI				
	175	34	V				
	176	35	V				
	177	29	VI				
	178	28	VI				
	179	27	VI				
	180	25	VI				
	181	24	V				
	182	23	VI				
	183	22	VI				
	184	21	VI				
	185	20	VI				
	186	19	VI				
	187	18	VI				
	188	17	VI				

[1] Outer islands

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